DOCUMENT RESUME

ED 298 900 IR 013 285

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TITLE Split-Brain Theory and Recent Results in Brain Research: Implications for the Design of Instruction.
PUB DATE 84
NOTE 11p.; In: Instructional Development: The State of the Art, II; see IR 013 273. For volume I, see ED 292 444.
PUB TYPE Information Analyses (070) -- Viewpoints (120)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Brain Hemisphere Functions; *Instructional Design; Lateral Dominance; Learning Processes; *Long Term Memory; *Neurolinguistics; Psychological Studies; *Short Term Memory; Visualization
IDENTIFIERS *Triune Brain

ABSTRACT

This review of the literature on the workings of the brain in relation to learning and instructional design reviews recent research on both long- and short-term memory, and discusses findings on lateralized or "split-brain" functions. Problems associated with short-term memory are also considered, and the concept of the Tribune Brain is discussed. The chapter concludes by discussing the implications of this research for instructional design. Two figures are provided. (35 references) (EW)

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Chapter 12

Split-Brain Theory and Recent Results in Brain Research: Implications for the Design of Instruction

James D. Hand

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The primary instrument used by instructional developers in creating, evaluating and modifying learner behavior through learning, changing attitudes and providing experiences is not the computer brain, as some books would lead one to believe, but the human brain. If we are to properly program an environment to interact with a brain so as to achieve our objectives, we must understand the workings of the brain. The following chapter summarizes recent thought and research on this topic, and draws implications for I.D.

INTRODUCTION

Much has been written of late on how the brain functions while taking in information, during storage processes, and during retrieval. Research has lead to new conceptualizations of brain functions and a great many new facts have come to light. Enough is now known about the brain to begin synthesizing the research results and applying them to the design of instruction. It is still too early to make hard and fast judgments, because applied research regarding brain function, learning and memory in the classroom is just beginning in this country. The implications of the results of basic research studies seem clear enough and, at the very least, point the way toward the types of educational research needed in order to confirm the educational importance of these works.

This paper attempts to answer two questions:

1. What do we know about how the brain functions during learning?
2. What do brain-function data suggest regarding the design of instruction?

The extent to which each of these can be answered is, of course, limited by the amount, types, and quality of research currently being reported.

INFORMATION INTAKE

Learning may be divided into general steps: intake of information, short-term memory storage (STS), and long-term memory storage (LTS). The intake of information is a complicated process. We are bombarded with stimuli from all of our senses during our waking hours, yet we attend to only a very few. This is accomplished by innate masking-mechanisms which are employed to suppress inputs from less-important stimuli while the brain focusses its concentration upon the more important inputs. The brain rapidly selects those cues which are important and allows them to enter the short-term memory store. It takes just 100 msec. (one-tenth of a second) to process pictorial information (Franken and Rowland, 1979). Kimura (1973) found that a 200 msec. sound duration involving a vowel and a consonant was all that was needed for processing speech into the left brain. Hyden (1977) reports that the retention of written words, singly or in common phrases, requires approximately 250 msec. (one-fourth of a second). While none of these studies were conducted as substained learning/studying sessions, they indicate a **potential** for listening rates of up to 300 words per minute (consistent with findings in instructional

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media research) and reading rates ranging from 240 wpm (for those who read by the line). This, too, is consistent with findings from research on reading. The amazing part of information-intake is the phenomenal possibility that the brain may be able to comprehend pictures at the rate of 600 per minute, based upon the capability of processing one picture each 100 msec. This rate is, of course, affected by the content and pattern complexity of the picture in question.

Information which is allowed into the brain by activated neurons is immediately channeled to several portions of the brain. Each of these is a storage site for certain types of information. If the receiving person decides to attend to the stimulus, the process of short-term memory storage will begin.

The implication which may be drawn from research on the brain's information-intake abilities is that, when concentrating, a person can bring in far more information than is normally presented during a lecture or during an hour of reading. This will be discussed further under "Long-Term Storage and Retrieval."

SHORT-TERM STORAGE

Recent research indicates that when a person is paying attention to a particular set of stimuli, electrical wave-patterns can be determined over several centers of the brain (Pribram, 1979). Proteins present in membranes of nerve cells, synapses and glia apparently enable the activation of vast numbers of neurons simultaneously. These proteins may provide the mechanism for the transformation of shifting electrical fields into molecular and cellular effects (Hyden, 1977). In short, proteins are present and active when input is made, and they then change as both short-term and long-term memory are established.

The short-lived reversible nerve protein changes and long-lasting remaining cell-protein changes are biochemically correlated. Within minutes after the brain's decision to attend to a stimulus, the hippocampus generates a short-lasting protein which will exist for about 24 hours. The same type of brain-cell protein production follows in the brain cortical areas after a certain delay. During learning, at least two other protein fractions are synthesized in the synaptic membranes. This guarantees that long-lasting nerve-cell changes will be made, helping establish a long-term memory.

When learning starts there is an increased systhesis of messenger RNA in nerve cells which induces the production of certain proteins and molecular patterns. Calcium helps translate electrical field charges into short-term molecular charges in brain-cell membranes. In short, the role of proteins and calcium are critical to learning. This confirms the research by Krech (1967), who found that proper nutrition six months prior to birth through six months after, concentrating on proteins and calcium, has marked effects upon brain weight, density and levels of synaptic chemicals in rats. From Hyden's research (1977) it is apparent that these same factors impact upon development of the human brain.

> "The working hypothesis is that the protein differentiation, caused by experience and learning, will secure the concomittant activation of all the neurons which have undergone a similar differentiation and on the same stimulus. It does not matter in what part of the brain the neurons are located. ...at learning neurons become highly active. The learning mechanism of the brain in the first hand is **active** not **reactive** like a reflex in a conditioned system (Hyden, 1977)."

The activation of neurons and the resultant protein changes which occur as short-term memory is formed also pave the way for more-permanent protein synthesis, which lays down the long-term memory store.

Researchers in the realms of biochemistry, electrophysiology and other neurosciences have gone beyond asking how memory is established to investigating where certain types of memories are stored. This led to studies of the lateralization of brain functions, commonly known as "split-brain" research.

LATERALIZED OR "SPLIT-BRAIN" FINDINGS

For centuries man has entertained the idea that one's logical self was somehow separate and distinct from one's emotional self. When scientists exhausted the possibilities of finding emotional centers in the heart and liver they turned, fortunately, to the brain. Broca and Wernicke were among the first to identify speech-areas of the brain, through dissection of deceased aphasics. Over the next hundred years scientists attempted to map areas of the brain which house and control various human capabilities. Lateralization of brain functions, the study of such maps, became a valid field of study.

Kimura (1973) revealed in a popularized article that auditory, visual, and manual tasks involving theoretical symbols (words and numbers) are handled **predominantly** by the left hemisphere of the brain, while qualitative symbols (spatial, nonverbal, and sensory) are processed **predominantly** by the right hemisphere. It must be emphasized at this point that Kimura's research and all others found by this author indicate that **both** hemispheres share in each type of mental activity. While one hemisphere may contribute more than the other to certain tasks, the hemispheres do not function as entirely separate structures, except in surgically-severed brains and in certain experimental settings. In other words, it is inappropriate to state that the processing of oral language is entirely the domain of the left

hemisphere, or that processing of pictorial information is entirely the domain of the right hemisphere. As an example, Kimura (1973) showed a test-ratio of hemispheric dominance for processing spoken words at 1.88:1 in favor of the left hemisphere. This indicates that approximately two-thirds of the auditory word-processing involved in that particular test occurred in the left hemisphere. The ratio of stereoscopic depth perception as tested by Kimura (a "right brain function" in common parlance) was 1.28:1 in favor of the right hemisphere. In both of these cases, and all others reported by Kimura, right and left hemispheres shared the functions, albeit unequally. Therefore, while each hemisphere specializes in controlling and storing different types of information, each relies upon the other to some extent for a complete view of the world. In those with normal, healthy brains the corpus callosum and the anterior commissure connect the opposite cortical lobes and their corresponding regions of the two hemispheres. These connecting pieces ensure the sharing of functions as discussed above.

Specialization is a fairly well-established scientific concept. Certain inputs are better processed by one hemisphere than by the other. Additionally, certain **outputs** are controlled predominantly by one side. Which side, and the **degree** of control, are partly functions of age, sex, handedness, and cultural upbringing (Debes, 1977; Gazzaniga and LeDoux, 1978; Geffen, 1976; Geschwind, 1979; Krashen 1973; McGlone, 1978; Webster, 1977). In general, for persons in Western Culture, each hemisphere has predominant specialization for the following (Eccles, 1977):

Left Hemisphere	Right Hemisphere
verbal inputs	nonverbal inputs
linguistic outputs	musical processing
ideation (abstractions)	pictorial and pattern sense
conceptual similarities	visual similarities
analysis over time	synthesis over time
analysis of detail	holistic images
numerics, quantities, arithmetic	intonations, verbal emphasis
logic, sequence information	location in time and space
controls right side of body	controls left side of body
geometric configurations	intuition, attitudes

This holds true for 95% of the tested adult right-handed males from Western cultures. But what of the exceptions, which are considerable? Looking only at the laterality of speech processing we find the following:

- Adult females of Western Cultures show relatively more symmetry between the hemispheres for both verbal and performance (nonverbal) tasks (McGlone, 1978);
- Left-handed adult males and females with a family history of left handedness, tested in the United States, show that for 65% of them the right hemisphere is the primary verbal site (less so for the females, as indicated above) (Kocel, 1977);
- Children who are prepubescent show no statistically significant differences between the lateralization of male and female brains (McGlone, 1978);
- Right-ear advantage for spoken words (which are directed to the left hemisphere) for right-handed subjects reaches statistically significant proportions at age 4 (Geffen, 1976), or perhaps age 9 or 12-14 years as indicated by other researchers. In other words there is a time prior to puberty during which both hemispheres process spoken language, as evidenced by children who maintain normal reading, listening, speech, and writing abilities after left-hemispheric brain damage (Gazzaniga and LeDoux, 1978);
- Adults brought up in the Japanese culture who have learned both Kanji and Katakana as native languages show strong speech and writing skills in both hemispheres. Kanji is ideographic/pictorial, with characters simultaneously representing both a sound and a meaning. This language is represented bilaterally using both portions of Wernicke's area across the corpus callosum. Katakana is syllabic and structured much as English. Left-hemispheric damage destroys the person's ability to perform in Katakana, yet damage to **either** hemisphere still leaves the person able to communicate in Kanji. Japanese raised in Western cultures do not show these traits, indicating that the difference is cultural rather than genetic (Geshwind, 1972; Debes, 1977).

Despite the exceptions listed above, yet accounting for them also, some tentative suggestions can be advanced for the design of instruction. We have yet to discuss long-term memory research. At that time we will cover research concerning coding and retrieval strategies. For now, the discussion will be limited to initial inputs for short-term storage.

Audio. Auditory stimuli not related to words and numbers is best processed and primarily stored by the right hemisphere, entering through the LEFT EAR. Reproductions of the human voice speaking words and numbers are best processed and primarily stored in the left hemisphere from the RIGHT EAR. Remember, however, that voice intonation, inflection, and other non-verbal aspects of speech are right-hemisphere predominant. WHAT you say goes to the left hemisphere; HOW you say it goes to the right.

Lozanov (1978) reports that if the learner is in a relaxed alpha-wave state, both hemispheres work in unison to process speech. When in an alert, active, beta-wave state, the brain processes and stores verbal input predominantly in the left hemisphere.

Visual: Words and Numbers. The eye is

neurologically wired to send impulses to both hemispheres. The left half of the visual field is sent to the right brain; the right half of the visual field goes to the left hemisphere. (See Figure 12-1.) When reading, the eye scans across the line from left to right (in our culture), picking up words and phrases in the right half of the visual field and sending them to the more theoretically-oriented left hemisphere. Because the eye scans verbal and numeric text, there is little advantage in attempting special placement of these stimuli in a display, **unless** there is pictorial information also being presented. In this case, the placement of the pictorial stimuli takes precendent, as described below.

Visual Pictorial. When pictorial and verbal/numeric stimuli are to be presented simultaneously, the picture should be placed in the left visual field. An excellent example of such a placement can be seen in the German language text **Deutsch 2000** by Max Hueber Verlag, printed in Germany. On the left portion of each page of a story are a series of drawings. At the right of each drawing are two or three sentences in German. The situation discussed in those sentences is graphically portrayed in the accompanying picture. While the learner's eye is scanning the lines of text, the left visual field of the eye is feeding pictorial information to the right hemisphere of the brain. The vocabulary is learned within the context of those graphics.

For purely pictorial representations, one can expect information presented to the right of the visual fixation point to be sent to the left brain. Cognitive recall, as verbalized by the learner, should be strongest for the 5° arc surrounding the

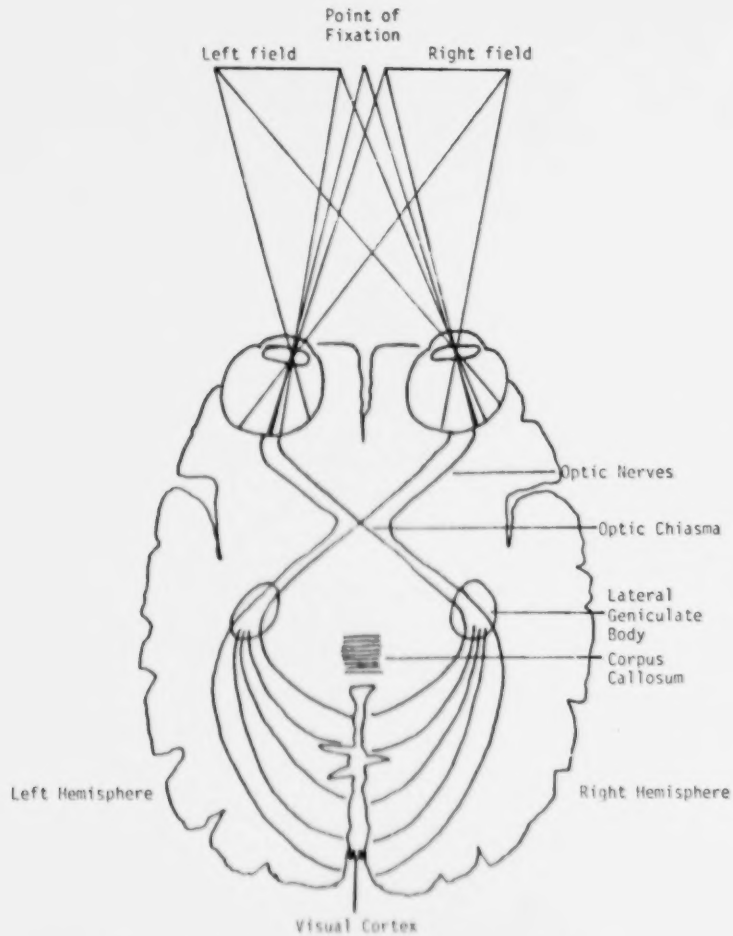

Figure 12-1. Each eye sends impulses to both sides of the brain. The left half of the visual field is sent to the right brain; the right half of the visual field goes to the left brain.

fixation point and for items immediately to the right of that. However, this author could find no studies of this phenomena in the literature to either confirm or deny this projection. Similarly, information located immediately to the left of the focal point should assist the right hemisphere in developing a feeling or attitude towards the content of the picture. Cognitive domain at the focal point and immediately to its right; affective domain at the focal point and immediately to its left. Once again, this is an hypothesis based upon anatomical research rather than upon educational research.

Tactile. The sensory cortex of each hemisphere interprets tactile data exclusively from the opposite side of the body. The motor cortex controls the motions of this same opposite side. For most learners this means that the hand and foot opposite the language-dominant side of the brain is somewhat better at carrying out actions which can be verbalized. When a language-dominant left brain says "We're going to need the socket wrench to pull that spark plug," the changes are very great that the mechanic's right hand will reach out and use that instrument. (The incidence of truly ambidextrous persons is very small, and that is perhaps the reason that there is very little evidence as to whether such persons have bilateral speech capacity.) If the same right-handed mechanic needed to gather tactile information about how smoothly the engine was running, the left hand (tied to the right brain) would be a somewhat better source.

THE PITFALL OF SHORT-TERM MEMORY

Short-term memory storage is also known as the "working memory." When a person actively thinks about and contemplates what is happening or draws information from the long-term memory so as to recall what has happened, the short-term memory is being employed. Unless what is in the working memory is committed to long-term storage, it will quickly be lost. Therein lies the pitfalls of masking, capacity, duration, item and order information loss, and recency (O'Keefe, 1978).

Masking occurs when items being processed are similar in some respect. If the items are to be remembered separately and distinctly, the differences between them must be stressed so that the brain can store them in separate categories or subcategories.

The capacity of the short-term memory is severely limited compared with that of the long-term memory. Aside from the role in short-term retention and specialized functions for language comprehension and generation, short-term memory maintains items "in a state of accessibility until they can be encoded into a contextual long-term memory system" (O'Keefe, 1978). Here, duration and recency enter into the equation. Through active rehearsal, recent inputs, including strong order identification, can be accessed by testing memory locations for recently-employed representations. Those used most recently will have lower synpatic thresholds, making it easier for the learner to recall the information. In the vernacular of students, this entire process is known as "cramming" for a test.

The pitfall for learners and teachers is that the student can juggle enough information in the short-term memory to pass most weekly or biweekly tests **without committing the information to long-term memory.** This indictment of short-term, noncomprehensive, factual recall tests is only half of the bad news. O'Keefe (1978) cites two studies which strongly suggest that verbal information in the short-term memory is stored in a "discrete neural area (the posterior parietal region), and not as a part of any causal short-term memory to long-term memory chain" (O'Keefe, 1978). If the learner is only memorizing words for temporary use, the chances of long-term retention are apparently minuscule.

Overcoming the pitfalls occasioned by the utilization of short-term retention for passing tests may be accomplished through several instructional strategies, such as:

- Rewarding the learner for correct use of the information in solving problems, as in simulations, essay responses, term papers, or even well-constructed multiple-choice questions for which the student must make several decisions prior to reaching a conclusion;
- The "discovery method," in which the learner must analyze and synthesize information in order to discover an underlying principle;
- Inductive-deductive switching, in which the instructor uses one of these methods for presenting information and then directs the learner to situations, problems, or test items which ask the student to use the other thought process.

Other methods, such as "overlearning," will be discussed under "long-term memory storage," which follows.

LONG-TERM MEMORY STORAGE

Information entered in long-term storage (LTS) is multiply encoded i.e., specific aspects of an experience are stored in multiple locations in the brain because the experiences themselves have multiple aspects (Gazzaniga and LeDoux, 1978). Much of the brain has been mapped in terms of the function and type of information stored in given sites. Thus, through electroencephalography using scalp electrodes and other noninvasive techniques, the researchers can determine some of the cortical areas active during an instructional event. This, in turn, reveals something about the sensory inputs being processed. Similarly, the researchers can map the active areas of the brain during recall and compare these areas to those active during information gathering. Thus far, Pribram (1979) and

others point out, there is a very high degree of correlation between the areas active during both intake and recall, both in terms of latency (delay of activity) and amplitude (voltage of the encephalogram).

During learning for LTS, many millions of neurons from different brain centers apparently are activated. Each activation seems at first to be localized within its own center, but soon spreads by association mechanisms to other parts of the brain. The paths along which these activations occur eventually lead to the entorhinal and related areas in the cortex and pass on to the hippocampus. The hippocampus does not seem to store new information; instead, its cellular mechanisms--electrical and molecular--are activated. The induction of biochemical activity, inducing protein differentiation of nerve cell membranes and synapses, spreads to different areas of the cortex via subcortical connections. The biochemical definition of **learning,** then, is protein differentiation of brain cells governed by the genetic mechanism (Hyden, 1977).

It is supposed that the same stimuli which induced protein differentiation in brain cells during learning can activate all brain cells, wherever they are located, during retrieval, provided only that they share the same pattern of protein differentiation. All similarly differentiated cells have the same qualitative and quantitative values in the space/time coordinates of contextual memory. The sum of these differentiated activations in the brain is considered to be the contextual memory.

Types of LTS Memory. Many neurobiologists, as cited by O'Keefe (1978), now believe that there are two basic LTS systems: the **taxon system** and the **locale system.** The workings of the latter are as described above. The mechanisms of the taxon system are not as well defined. The taxon LTS is not contextual, is not time-referenced, and is rote in nature. If the spelling of the word R-E-T-R-I-E-V-A-L is difficult for you, your taxon system may be at fault because the "E" after "I" rule should be employed. If you memorized the names of the Presidents in serial order, with no real concept of the time at which each served, the taxon system LTS would be the one employed. Unless this information were somehow stored **contextually** within the locale system, you would find it difficult to use the list of Presidents for any type of problem solution. This would also be the reason why health science students (medicine, nursing, dentistry, and pharmacy, for example) who memorize drug names, indications and contra-indications for use, and potential side effects by using the taxon LTS, have difficulty in solving case-problem test items for which the locale system's LTS must be used.

More explicitly, the locale system includes time/space coordinates for fixing events in spatial and temporal relationships. There have been times in nearly everyone's lives when they have met a person for the second time, yet failed to remember that person's name: an embarrassing failure of the taxon system. Yet, after some thought, you are able to construct the situation in which you first met the person - who else was present, what the surroundings were like, what activities you engaged in. This context, fixed in time and place, has been preserved in the locale system LTS.

In summary, the features of these two LTS systems are as follows:

Taxon System
- categorization by features similarity.
- abstraction of prototypes which incorporate critical attributes of the category members (models).
- absence of spatio-temporal context coding.
- consequent absence of order, time and place information.
- substantial decay over time.

Locale System
- preservation of spatio-temporal context.
- single-occurrence storage
- minimal interference between different representations of the same item.
- multiple channels of access for retrieval of any, or all, of the relationships embodied in the memory.
- relatively permanent (O'Keefe, 1978).

Memories which rely primarily upon one communication mode will be nearly context-free, which means that they will be stored in the taxon system and are subject to decay unless used often. The neuronal threshold can be kept low through repetition and practice of those items in taxon LTS.

Memories which are encoded from multiple stimuli form a context which is apparently stored in the locale LTS. These memories are, according to Pribram (1979), holographic in nature and can be retrieved by stimulating brain cells by simulating some of the circumstances under which the memory was formed.

IMPLICATIONS FOR DESIGNERS OF INSTRUCTION

(1) If what is to be learned is rote, verbatim, categorical or rule-oriented, the taxon system LTS should be emphasized.

An example of this would be the first step in teaching the concept "mammal" by defining the critical attributes: warm blooded, female gives live birth, female suckles its young. If this set of abstractions is practiced until everyone in the class can recite the definition verbatim the taxon LTS has been encoded for "mammal." **Overlearning** enhances recall from the taxon system through lowering the neuronal threshold.

(2) If that which is to be learned must be applied to new and different situations, the locale (contextual) LTS should be emphasized.

The former example was predominantly

verbal and without context. If we now wish the learner to apply the definition of mammal by selecting examples and non-examples of mammalia from a list of animal names or pictures, then a context must be taught so that the memory of "mammal" is established in the locale system. Herein lies another strong implication. Clarity of a memory is enhanced by increasing the number of neurons and brain centers activated when memory is recalled from LTS to short-term storage. The number of neurons and centers activated during recall is limited to the number used to attend to and store the information in the first place. Maximizing the number of neurons and centers can be accomplished by simulating the context within which the memory was initially formed.

(3) Being careful to not detract from the clarity of the message, use as many types of sensory and theoretical inputs as possible in establishing the learning context.

(4) When the information or process being learned has direct applicability to some future learning or use situation (such as a job task) the **learning should take place within a context as similar as possible to the context within which it will be used in order** to enhance recall.

(5) Design tests so as to measure the information stored in the same LTS system your teaching was designed to store it in.

It is unreasonable to assume that instruction designed to reach and be stored in the taxon system will automatically be posited in the locale system as well, and vice versa.

(6) When teaching for storage in the locale memory, stress visual representations.

Haber (1970) and Franken and Rowland (1979) have found that the picture memory of humans is remarkably efficient. There is tremendously large storage capacity for pictorial representations and, therefore, for visual **contexts** with which to associate other items for recall. While most picture memory loses detail, the meaning or sense of the representation is retained, with enough of the pattern to reconstruct most of the main elements portrayed in the original picture.

(7) At the conclusion of the learning session, have the learners relax for a few moments while they rehearse what they have just seen or heard.

Memory practice and verbal associations between what was said and what was seen increased subjects' ability to recall and uncover previously-unremembered details in Haber's study (1970). The 'old saw' that a student should take a break and do something entirely different at the end of a study session was discovered to be a detriment to learning.

(8) Combine as much as possible into a single impression.

If a series of items or steps must be mastered, it is best to teach them as discrete elements **at first.** Once they are mastered, the student will be able to recall them more easily as a **set.** In teaching someone to drive an automobile or perform cardiopulmonary resuscitation, there are literally hundreds of separate steps to master. In the end these steps should be logically grouped into sets such as "starting the car," "parallel parking," or "external cardiac massage." This becomes one form of mnemonic, an interactive mnemonic (Higbee, 1979).

(9) The more vivid and active the impression of what is being learned, the stronger the memory trace.

Imagine for a moment the level of neuronal excitement in a child's brain when a teacher says, "Now listen, class, because this **will** be on the test Tuesday. George Washington was born on February 11, 1732. His birthday changed to February 22nd in 1750 with the advent of the Gregorian calendar." Now imagine a creative teacher who role-plays Washington, or asks a parent to do that; or shows a movie in which Washington and Franklin sit at a table and attempt to calculate what their "new" birthdays will become under the Gregorian calendar. The context of seeing two men in eighteenth-century dress in a home of that era, by candlelight or oil lamp light, speaking Early American English, would obviously produce a more vivid and active impression than just the teacher's voice doling out pearls of wisdom.

Lozanov (1978) and Higbee (1979) indicate that it apparently matters whether this vivid, active imagery is developed externally or internally. Those who have a high ability for mental imagery finds self-generated mediators more effective, while those with low ability (such as the very young and mental retardates) find images more effective when supplied by others.

(10) Practice is essential, but it has to be the right kind.

Practice to enhance taxon memory should be rote: short, simple, and ordered in logical sequence. Practice to enhance locale memory should incorporate several types of symbols, verbalizations, and sensory channels.

(11) Recall is more difficult (limited) than is recognition.

Recall calls upon the verbal system as well as upon the nonverbal. The verbal system can only report that which is stored there. Therefore,

(12) Recitation or writing the information from one's own thoughts will enhance verbal recall.

The verbal portion of the brain has limited capacity, so only the most important, verbally-practiced information is stored.

In a recognition task, nonverbal centers have an opportunity to express themselves by pointing to or selecting from a series of objects. With this response available for tasks such as multiple-choice and matching test items, all information that the multiple nonverbal systems have stored can be reported, making the student seem more resourceful than he would if a recall question is asked.

(13) Ask the learner to verbalize during perceptual experiences.

When information of a perceptual nature, regardless of the input modality, is encoded while the information is being simultaneously verbalized, the internal language system is active, and the information is encoded verbally as well as nonverbally, and a bond forms which allows the language system some access to memories laid down by the nonverbal systems.

THE TRIUNE BRAIN

Recent work by MacLean (1973; Holden, 1979) at the National Institute for Mental Health's Laboratory of Brain Evolution and Behavior has led to the development of a brain-structure model termed the "triune brain." "Triune" refers to three separate and distinct functional entities composing the brain: the reptilian complex (R-complex), the limbic system, and the relatively massive neocortex. These three portions hold quite different mentalities, according to MacLean, each with its own special abilities, its own view of the world, its own sense of time and space, its own memories, and its own motor and other functions (Sagan, 1977). These three portions act as interconnected biological computers developed sequentially **in utero.**

They "are said to be distinguished neuroanatomically and functionally, and contain strikingly different distributions of the neurochemicals dopamine and cholinesterase." (Sagan, 1977)

Our behavior may be determined by any one of these portions of the triune brain, depending upon circumstances, past experiences, and genetically-programmed survival mechanisms. MacLean's experiments indicate that the R-complex plays an important role in aggression, "territoriality, ritual and the establishment of social hierarchies" (Sagan, 1979). It appears that basic needs and sexual drive are programmed in this portion of the triune brain.

The limbic system apparently controls strong and vivid emotions, attitudes, prejudices, and motivations not tied to basic biological needs. It is in the limbic system tht hippocampus, which triggers long-term memory storage, is housed. The pituitary gland, also located here, controls the endocrine system. Imbalance in this system alters moods, which provides an important clue to the relationship between the limbic system and our attitudes and mental states. Malfunctions of the pituitary, amygdala, hippocampus and other limbic organs can lead to rage, fear, or sentimentality that have no readily-apparent cause (MacLean, 1973).

The neocortex, which virtually surrounds the limbic system (which in turn surrounds the R-complex), controls characteristically human intellectual functions. Logic and the quest for knowledge are apparently controlled by this portion of the brain, as are the anticipation of the future, anxiety, language processing and other indicators of intellect.

While short-term memory and the triggering mechanisms for long-term storage are primarily limbic-system functions, long-term memories are stored in all three portions of the triune brain. Each portion is the site for storage of specific types of information, related to the abilities of that particular portion: ritual in the R-complex, emotion in the limbic system, and reason in the neocortex. Similarly, selective attention to stimuli is controlled in the three areas by the abilities of each. For example, the R-complex will attend to the student's hunger during a class at 11:30 a.m., the limbic system will concentrate upon how the student feels about the instructor or subject matter, while the neocortex is attempting to process the cognitive information being presented.

The R-complex apparently has preference in most situations. That is, if a person is overly cold in a classroom, emotions and the quest for knowledge will take a back seat to the need for warmth. The need for sleep will also overcome the neocortex and the limbic system. If the R-complex's needs are satisfied, the limbic system then has preference over the neocortex. The hippocampus must be ready to accept new information, as stated previously, before long-term learning can occur.

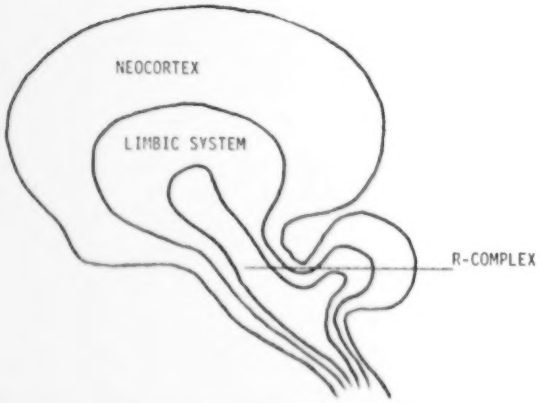

Figure 12-2. Highly schematic representation of the three portions of the Triune brain, after MacLean.

Finally, if both the R-complex and the limbic system's needs are satisfied, the neocortex can function optimally. The interconnectedness of these three allows the neocortex, at times, to dominate; that is, for reason to predominate over emotional and basic needs. This seems to be a short-term victory, however. It is a rare person, indeed, who can set aside emotion, attitudes, and basic needs for long periods of time. Recall, if you will, the research on attention spans at various ages and levels of educational development which indicate that an attention span greater than 30 minutes is most unusual. Research also points out that adolescents and young adults are interrupted by "romantic thoughts" (love, sex) five to twenty times per hour. These research findings indicate the high priority of R-complex and limbic system functions, to the detriment of neocortical functions.

> MacLean believes that the people who are enamored of theorizing about the differences between the left (rational, verbal) and right (nonverbal, intuitive) cerebral hemispheres are missing the boat somewhat. 'I think they've got a lot of stuff maybe too high upstairs' - that is, many of the creative, emotional and spiritual impulses ascribed to the right hemisphere are more properly attributable to the limbic system. (Holden, 1979)

Kimura's research results, cited earlier, are in agreement with this, in that the hemispheres share in carrying out functions, albeit less equally than MacLean believes.

MacLean's model of a triune brain provides a few implications for instructional design, most of which are previously-stated tenets but are nonetheless important to review.

> (14) For individualized self-study materials, the setting in which they are used is at least equally as important to learning as is the quality of content and design used to present the information.

Directions for use of self-study instructional materials should include suggestions for appropriate settings in which study may be most effective. If special equipment or other resources are to be used, this should be specified, along with information regarding where they are available, for how long they may be used, and other special circumstances which may impact upon the use of these resources. If the material can be used by pairs of students or by small groups for interactive study, directions should include suggestions for the most effective use of the materials in group discussion.

> (15) Clarity reduces unwarranted anxiety.

Explicit directions, unambiguous learning objectives, sample test items, practice and review items, clearly-drawn diagrams with appropriate labels, worksheets, and clearly outlined and stated textual material tend to let the learner know exactly what is expected by the instructor or author. This frees the limbic system and neocortex from unwarranted anxiety about the requirements of the lesson or course.

> (16) Examples used in instruction can effect the learner's attitude and mood. Effectiveness of examples may also be determined by the learner.

Examples which are clearly pertinent to the subject, or to the life-goals of the learner, provide a realistic backdrop for the information being learned. In many cases, the examples can draw upon esthetic appeal, empathetic situations or common positive personal experiences of the learners, all of which can have a positive influence upon the limbic system's view of the instruction. The affective portions of instruction must be attended to by the instructional designers so as to assist the learner in developing intrinsic motivation for storing the information in long-term memory storage. Developing a positive attitude toward learning the material, or at least avoiding the alienation of the learner, is important to hippocampal involvement in generating the proteins essential for long-term memory (O'Keefe, 1978)

SUMMARY

Over the past few years, research into brain function during information intake, learning, and recall has increased dramatically. Some of the recent studies were cited and discussed. The educational implications for the design of instruction are becoming somewhat clarified. Many of the tried-and-true instructional strategies are becoming somewhat clarified. Many of the tried-and-true instructional strategies are upheld by brain-function research, while other methods become questionable. Certain new strategies may become accepted as educational researchers investigate and validate them.

REFERENCES

Adey, W. R. Models of membranes of cerebral cells as substrates for information storage. BioSystems, 8 (1977), 163-178.

Atkinson, R., and Shiffrin, R. The control of short-term memory. Scientific American, 225 (Aug. 1971), 82-90.

Bisiach, E., and Capitani, E. Cerebral dominance and visual similarity judgements. Cortex, 12 (1976), 347-355.

Ciganek, L. A Comparative study of visual, auditory and somatosensory eeg responses in

man. Experimental Brain Research, 4 (1967), 118-125.

Debes, J. Visuocultural influences on lateralization. Annals of the N.Y. Academy of Sciences, 1977, 474-476.

Dimond, S. and Beaumont, G. Use of two cerebral hemispheres to increase brain capacity. Nature, 232 (1971), 270-271.

Eccles, J. Evaluation of the brain in relation to the development of the self-conscious mind. Annals of the New York Academy of Sciences, 299, (1977), 161-179.

Edson, L. Science probes a last frontier: the brain. Think, 36, 6 (Nov.-Dec. 1970), 2-8.

Franken, R. E., and Rowland, G. L. Nature and the representation for picture-recognition memory. Perceptual and Motor Skills, 49 (1979) 619-629.

Gazzaniga, M. S. and LeDoux, J. E. The Integrated Mind. N.Y.: Plenum Press, 1978.

Geffen, G. Development of hemispheric specialization for speech perception. Cortex, 12 (1976), 337-346.

Geschwind, N. Specializations of the human brain. Scientific American, 241 3 (Sept. 1979), 180-199.

Geschwind, N. Language and the brain. Scientific American, 226, 4 (April 1972), 76-83.

Haber, R. N. How we remember what we see. Scientific American, 222, (May 1970), 104-112.

Higbee, K. Recent research on visual mnemonics: historical roots and educational fruits. Review of Educational Research, 49, 4 (Fall 1979) 611-629.

Holden, C. Paul MacLean and the triune brain. Science, 204 (8 June 1979), 1066-1068.

Hyden, H. The differentiation of brain cell protein, learning and memory. BioSystems, 8, (1977), 213-218.

Kimura, D. The asymmetry of the human brain. Scientific American, 227, (March 1973), 70-78.

Kocel, K. M. Cognitive abilities: handedness, familial sinistrality, and sex. In S. Dimond and D. Blizard, Evolution and Lateralization of the Brain. Annals of the New York Academy of Sciences, Vol. 229 (1977), 233-243

Krashen, S. D. Lateralization, language learning and the critical period: some new evidence. Language Learning, 23 (1973), 63-74.

Krech, D. The chemistry of learning. Paper presented at the Charles F. Keetering Foundation and U.S. Office of Education, Three National Seminars on Innovation, Honolulu (HA), 21 July 1967.

Lozanov, G. Suggestology and Outlines of Suggestopedy. N.Y.: Gordon and Breach, 1978.

Lynch, G. S., Dunwiddie, T. and Gribkoff, V. Heterosynaptic depression: a postsynaptic correlate of long-term potentiation. Nature, 266 (1977), 737-739.

McFarland, K., and Ashton, R. The influence of brain lateralization of function on a manual skill. Cortex, 14 (1978), 102-111.

McGlone, J. Sex differences in functional brain asymmetry. Cortex, 14 (1978), 122-128.

MacLean, P. D. A Triune Concept of the Brain and Behavior. Toronto: University of Toronto Press, 1973.

O'Keefe, J. The Hippocampus as a Cognitive Map. N.Y.: Oxford University Press, 1978.

Oscar-Berman, M., Blumstein, S. and Deluca, D. Iconic recognition of musical symbols in the lateral visual fields. Cortex, 12 (1976), 3, 241-248.

Pribram, K. Holographic memory. Psychology Today, 12, 9 (Feb. 1979), 71-84.

Pribram, K. Hemispheric specialization: evolution or revolution. In S. Dimond and D. Blizard, Evolution and Lateralization of the Brain. Annals of the New York Academy of Sciences, 299 (1977), 18-21.

Rennels, M. Cerebral symmetry: an urgent concern for education. Phi Delta Kappan, March 1976, 471-472.

Sagan, C. The Dragons of Eden: Speculations on the Evolution of Human Intelligence. New York: Random House, Inc., 1977.

Shevrin, H., Smokler, I., and Wolf, E. Field independence, lateralization and defensive style. Perceptual and Motor Skills, 49 (1979), 195-202.

Shin-Ho, C. Synaptic memory in the hippocampus. Nature, 266 (1977), 677-678.

Webster, W. Territoriality and the evolution of brain asymmetry. Annals of the New York Academy of Sciences, 299 (1977), 213-221.